Chapter 1
What are the components of the male reproductive system?

CNS, pituitary, testis, epididymis, prostate, seminal vesicles, scrotum, penis

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The male reproductive system consists of organs acting in series to produce spermatozoa and deliver them to the female reproductive tract. The system is summarized in Fig. 1. Spermatozoa, the haploid germ cells, are produced in the testis and undergo maturational changes as they transit through the epididymis. The vas deferens transports the spermatozoa from the epididymis to the ejaculatory duct in the prostate. The spermatozoa and secretions of the seminal vesicles empty together, with secretions from the prostate, into the prostatic urethra. Finally, secretions from the bulbourethral gland contribute to the ejaculate as the mixture exits the body through the penile urethra. The entire system is dependent on testosterone, produced in the testis, whose levels are regulated by the pituitary and hypothalamus. Knowledge of the anatomy and embryological origins of the components of the male reproductive tract is essential in developing a complete understanding of the system and its common diseases and dysfunctions.

Testis

The testis is the site of germ cell development via the process of spermatogenesis and thus the primary organ of the male reproductive system. The testis is comprised of several seminiferous tubules, where germ cell development takes place. The seminiferous tubule is comprised of Sertoli cells, the epithelial cells of the tubule, with developing germ cells populating the space between adjacent Sertoli cells. Spermatogenesis begins with diploid spermatogonia that divide by mitosis to renew the population of stem cells. A subset of spermatogonia progress to enter meiosis, at which point they are referred to as spermatocytes. After the two cell divisions of meiosis, the resulting haploid gametes are referred to as spermatids.

Spermatids morph from round cells, with the normal complement of cytoplasmic organelles, to elongated, highly specialized cells through the process of spermiogenesis. Tight junctional complexes between adjacent Sertoli cells protect the meiotic spermatocytes and post-meiotic spermatids, both of which are immunologically unique, from the adaptive immune system. Fully formed spermatids are then released into the lumen of the seminiferous tubule and transported to the rete testis, the collection site in the testicular mediastinum, for transport into the efferent ducts leaving the testis. The interstitial space in the testis, outside of the seminiferous tubules, is populated by the Leydig cells, which synthesize and secrete testosterone, and the capillary blood vessels that supply the testis.

Scrotum

The function of the scrotum is to house and protect the testis and to help maintain the temperature of the testis optimal for spermatogenesis. The scrotum forms as an out pocketing of the abdominal parietal peritoneum, called the processus vaginalis, through the anterior abdominal wall into the scrotal swellings. As a consequence, the layers of the scrotum reflect the muscle and fascial layers of the abdominal wall. The testis descends into the scrotum late in development, passing through the inguinal canal with the processus vaginalis, pulling its vasculature, nerve supply, and the vas deferens with it. The cremasteric and Dartos layers of scrotal fascia contribute to the important temperature regulatory function of the scrotum by wrinkling the scrotal skin (dartos fascia) and pulling the testes close to the abdominal wall (cremaster muscle) to conserve heat and protect the testis. Successful testis descent into the scrotum is essential for fertility, as spermatogenesis requires a temperature 2-3 degrees C lower than abdominal temperature. The processes vaginalis detaches from the parietal peritoneum to become tunica vaginalis covering the testis. Failure of the tunica vaginalis to separate from the parietal peritoneum often results in a buildup of fluid inside the scrotum which is referred to as hydrocele.

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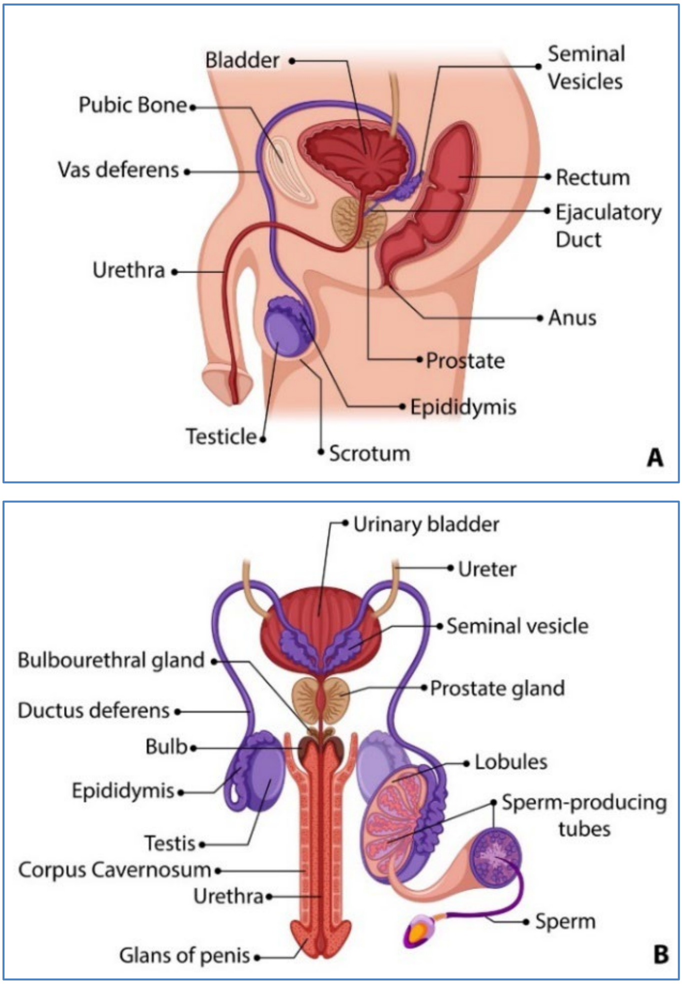

Figure 1A. Overview of the basic anatomy of the male reproductive track as it relates to the other structures of the pelvis. B. Diagrammatic depiction of the histology of the seminiferous tubules and structure of the testis, and the excurrent ducts of the male reproductive tract. (Adapted from https://www.vecteezy.com/free-vector/male-reproductive-system)

Epididymis

The epididymis is a single, highly convoluted tubule, six to seven meters long, connected to the rete testis by a series of efferent ducts.

The spermatids released from the seminiferous epithelium are immature in that they are non-motile and incapable of fertilization. The function of the epididymis is to bring testicular spermatozoa to functional maturity (Chapter 18). The maturation process includes changes in the phospholipid composition of the sperm plasma membrane and the addition and removal of specific proteins and other macromolecules to/from the maturing spermatozoa. How the epididymis accomplishes this maturation process is not fully understood. The epididymal epithelium secretes many proteins and other molecules, some packaged in exosomes, into the fluid in the epididymal lumen that bath the sperm. The components of this fluid provide the optimal micro-environment for the molecular changes that bring epididymal sperm to maturity. Mature epididymal sperm are stored in the distal part of the epididymis prior to ejaculation.

Vas deferens

The epididymal tubule ends by transitioning into the vas deferens (ductus deferens), a thickened and muscular continuation of this tubule that transports spermatozoa from the epididymis to the prostatic urethra. In its course, the vas deferens ascends from the distal epididymis in the scrotum, with the vessels that vascularize the testis and epididymis, passes through the inguinal canal, and crosses behind the bladder to enter the prostate. The ejaculatory duct, formed from the terminal portion of the vas deferens, passes through the substance of the prostate to connect the vas deferens to the prostatic urethra. The primary function of the vas deferens and ejaculatory duct is the transport of mature spermatozoa and seminal vesicle secretions (discussed below) to the prostatic urethra.

Seminal vesicles

The seminal vesicles reside immediately above the prostate gland, posterior to the bladder, and are connected to the ejaculatory ducts. The seminal vesicles are comprised of a series of tubular alveoli lined with a very active secretory epithelium (Chapter 21). In fact, the seminal vesicle contributes the majority of the fluid volume of the ejaculate (~70%). Seminal vesicle secretions are rich in fructose and prostaglandins. The seminal vesicle also produces several androgen-dependent secretory proteins, including semenogelin, that are involved in such processes as the coagulation of the ejaculate and immunoprotection of the sperm when deposited in the female reproductive tract.

Prostate

The prostate gland is located in the space inferior to the bladder and superior to the perineal membrane. Its location, immediately anterior to the rectum, allows the prostate to be palpated and biopsied through the anterior wall of the rectum. The prostate arises from several distinct sets of tubules that evaginate from the primitive urethra, each developing into a separate lobe. The lobes are composed of alveoli, lined with a secretory epithelium, that drain through a series of converging tubules into the mid-region of the prostatic urethra. The lobes are essentially continuous in the adult human prostate, with no apparent gross or morphologic distinctions (Chapter 20). A more clinically useful anatomical description of the prostate gland distinguishes prostatic zones based on morphologic and functional properties (i.e., central, peripheral, and transition zones). Certain zones are associated with specific pathologies (i.e., prostate cancer arises preferentially in the peripheral zone and benign prostatic hyperplasia in the transition zone).

Prostatic secretions contribute significantly to the fluid volume of the ejaculate (~25%). These secretions are high in zinc, citric acid, and choline and several secretory proteins, including acid phosphatase, plasminogen activator, and prostate-specific antigen (PSA). The exact roles of most prostatic secretions are unknown, although they are presumed essential for the function of spermatozoa during and after ejaculation. Many of the proteins are proteases involved in the liquification of coagulated ejaculate. An elevated level of PSA in the blood is often correlated with abnormal prostatic growth, such as cancer or benign hyperplasia of the prostate.

Penis

The penis is responsible for delivering male germ cells to the female tract during sexual intercourse. It is comprised of two corpora cavernosa and the corpus spongiosum. The corpora cavernosa are erectile tissues that when filled with blood, produce the penile erection. The corpus spongiosum, also an erectile tissue, surrounds the penile urethra and forms the glans penis. The penile urethra is continuous with the prostatic and membranous portions of the urethra and provides the remaining conduit for the sperm and ejaculatory fluids (seminal plasma) as they leave the body. The physiology of penile erection is complex, disorders of which lead to erectile dysfunction (Chapters 50 & 51). The importance of proper erectile function to sex and reproduction, and the common occurrence of erectile dysfunction (affecting 10-20 million men in the United States), have made erectile dysfunction a primary clinical concern in andrology.

Development of the Male Reproductive Tract

The testis arises from the primitive gonad. Primitive germ cells migrate to the undifferentiated gonad from the yolk sac, causing the coelomic epithelial cells to proliferate and form the sex cords. The formation of the sex cords gives this region a raised contour called the genital ridge. During the fourth month of fetal development, the sex cords become U-shaped, and their ends anastomose to form the rete testis. At this point, the primordial sex cells are referred to as pre-spermatogonia and the epithelial cells of the sex cords as Sertoli cells. The sex cords will become the seminiferous tubules. The rete testis extends into the mesonephric tissue and will anastomose with some of the mesonephric tubules forming the efferent ducts that communicate with the forming epididymis. The mesenchymal tissue in the interstitial space between the tubules gives rise to the Leydig cells, the site of androgen synthesis and secretion.

The epididymis, vas deferens, and seminal vesicles have a common origin from the mesonephric (Wolffian) duct. Initially formed as the early embryonic excretory system, the mesonephric system is comprised of a longitudinal duct and a series of tubules that branch from the duct toward the developing gonad. Although most will degenerate, several of these tubules persist and anastomose with the confluence of the seminiferous tubules (rete testis) to form the efferent ducts through which spermatozoa exit the testis. The portion of the mesonephric duct closest to the efferent ducts elongates, becomes extensively convoluted, and forms the epididymis. The epididymis remains in close contact with the testis and descends with the testis into the scrotum. The distal part of the mesonephric duct forms the vas deferens and ejaculatory duct. An out pocketing of the mesonephric duct just proximal to the developing ejaculatory duct develops into the seminal vesicle. The prostate forms from a set of tubules that evaginate from the primitive urethra and not from the mesonephric duct.

Endocrine and nervous control of the male reproductive tract

The entire male reproductive tract is dependent on hormones for proper function. The pituitary produces gonadotropins, follicle-stimulating hormone (FSH) and luteinizing hormone (LH), under the control of gonadotropin-releasing hormone (GnRH) secreted by the hypothalamus. FSH acts on Sertoli cells and is required for the initiation and quantitative maintenance of spermatogenesis (Chapter 2). LH stimulates androgen production by the testicular Leydig cells. Testosterone, acting on Sertoli cells, is required in high concentration to maintain the process of spermatogenesis. The male sex accessory organs are also all dependent on androgen for proper development and function. In addition to hormonal control, the reproductive organs are also subject to sympathetic and parasympathetic nervous control. This is particularly true for the erectile function of the penis, that is under parasympathetic control, and for ejaculation, that is under sympathetic control.

Conclusion

This brief introduction to the male reproductive tract demonstrates the serially integrated nature of the system. The seminiferous tubules are continuous with the penile urethra via the epididymis and vas deferens, together comprising a tubular transit of around eight meters, with the accessory organs contributing their secretions along this course. The entire system is maintained by pituitary gonadotropins, and androgens secreted by the testis. Understanding the anatomy and embryological development of the components of the male reproductive tract are key to understanding its normal function, as well as the common, and the not-so-common, disorders encountered in the clinic.

Suggested reading

Sadler TW. Urogenital System. In: Langman's medical embryology. 14th ed. Philadelphia: Wolters Kluwer; 2019. p. 256-283. Chapter 16.

Tanagho EA, Lue TF. Anatomy of the Genitourinary Tract. In: McAninch JW, Lue TF, editors. Smith & Tanagho's General Urology, 19e. New York, NY: McGraw Hill; 2020. Chapter 1.

Tanagho EA, Nguyen HT, DiSandro M. Embryology of the Genitourinary System. In: McAninch JW, Lue TF, editors. Smith & Tanagho's General Urology, 19e. New York, NY: McGraw Hill; 2020. Chapter 2.

The Male Reproductive System. In: Mescher AL, editor. Junqueira's Basic Histology Text and Atlas, 16th ed. New York, NY: McGraw Hill; 2021. Chapter 21.

Walsh TJ, Smith JF. Male Infertility. In: McAninch JW, Lue TF, editors. Smith & Tanagho's General Urology, 19e. New York, NY: McGraw Hill; 2020. Chapter 44.

White BA, Harrison BA, Mehlmann LM. The Male Reproductive System. In: Endocrine and Reproductive Physiology, 5th ed. St. Louis: Elsevier Inc; 2019; Chapter 9.